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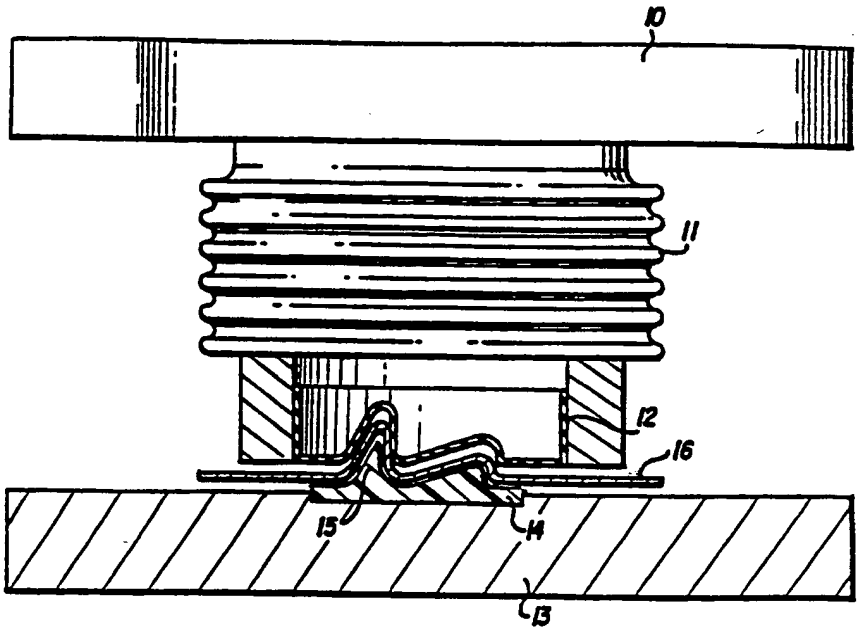
(54) Title: TRANSFER FIXTURE AND PROCESS FOR PRINTED CIRCUIT BOARDS

(57) Abstract

This invention relates to an apparatus and method for uniformly transmitting pressure to laminate a conductor or printed circuit to an at least two-dimensional substrate surface so that the bonding of one to the other is uniform across the surface including the periphery of the surface. The invention includes multiple platens disposed opposite each other. One platen contains a cavity for insertion of a substantial thickness of the substrate while the other platen has attached to it a cylinder having portions of its volume divided by multiple diaphragms. One of the diaphragms is a mold shaped to be a mirror image of the surface of the substrate, and which is confined in the distal end of the cylinder. An alternative embodiment is directed to the use of a bellows attached to the noted platen in place of the cylinder. The bellows has at its distal end the mentioned mold. This technique permits not only a uniform lamination technique, but also provides a technique for eliminating the hazard of using a bladder with hot pressurized fluid which can burst or jet fluid at personnel.



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TRANSFER FIXTURE AND PROCESS FOR PRINTED CIRCUIT BOARDS

Related Applications

This application is a continuation-in-part of Application Serial No. 214,380, filed July 1, 1988 and United States Application Serial No. 343,741, filed of even date, to the same inventors as this application, entitled "Apparatus and Method for Fabricating Printed Circuit Boards". The applications have the same assignee. These applications are hereby incorporated by reference.

Field of the Invention

This invention relates to pressure transmitting apparatus and processes to effect uniform transfer pressure of a conductor to a substrate to obtain uniform bonding of one to the other across two and three-dimensional surfaces of the substrate. The conductor is preferably a printed circuit located on a release medium.

Background Art

The art area has been directed to forming circuit boards by techniques other than transferring a conductor to a substrate used to form the circuit board. The art area has been concerned principally with lamination of multilayered circuit boards.

For example, United States Patent No. 4,029,845 relates to a thermosetting resin in which of heat and pressure are used to form a composite circuit board. The reference only discloses forming the baseboard and does not teach forming printed circuit elements on that baseboard. The reference refers to an additive process for manufacturing a printed circuit board without explanation of that teaching.

United States Patent No. 4,180,608 teaches heat and pressure used to form a composite printed circuit board. However, the reference uses a carrier layer for resin but not a printed circuit as in the present invention. A lamination is formed as taught in the art.

As examples of methods and apparatus for molding structural parts, United States Patent Nos. 3,642,415; 3,669,806 and 4,243,368 teach diaphragms used to form plastic sheet material. Pressure is transmitted using a fluid. Regarding the '806 patent, the reference does not teach bonding of an electrical conductor to a substrate. While teaching a controlled bonding force ensuring engagement of components in the '806 patent, it does not teach the present invention.

U.S. Patent No. 4,148,597 teaches use of a fluid pressure force to form an irregular shape by applying that force to a silicone rubber mold. U.S. Patent 3,255,476 teaches a press for irregularly shaped articles.

U.S. Patent No. 4,729,730 teaches a pressure transmitting apparatus using a superplastic alloy as the pressure transmitting medium. The apparatus is designed so that the alloy medium will not spread out in the event that the apparatus breaks. The preceding references are all incorporated by reference.

This invention overcomes disadvantages found in the prior art which relates to laminating printed circuits to substrates, particularly those substrates which have complex shapes.

Summary of the Invention

This invention relates to a uniform pressure transmitting apparatus for uniformly laminating a conductor to an at least two-dimensional substrat

surface comprising, (a) a first platen means having a fluid filled bellows with a first cavity means substantially confining a mold which is a mirror image of the at least two-dimensional substrate surface, (b) a second platen means containing a second cavity means dimensioned to protrude a portion of the thickness of the substrate, (c) pressurization means for compressing a conductor overlaid on the substrate surface, and (d) laminating means to bond the conductor to the substrate surface.

This invention also relates to a uniform pressure transmitting apparatus for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, (a) a first platen means having a fluid filled bellows with a first cavity means substantially confining a mold which is a mirror image of the at least two-dimensional substrate surface, (b) a second platen means containing a second cavity means dimensioned to protrude a portion of the thickness of the substrate, (c) pressurization means for compressing a printed circuit positioned on the substrate surface, and (d) laminating means to bond the printed circuit to the substrate surface.

This invention further relates to a method for uniformly laminating a conductor to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of the substrate in a cavity means of a platen means, positioning a conductor on the substrate surface, applying a uniform pressure to the conductor and substrate surface using another platen means having a fluid-filled bellows containing another cavity means which substantially confines a mold, which is a mirror image of the at least two-dimensional

substrate surface, and laminating the conductor to the substrate surface.

This invention also further relates to a method for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of the substrate in a cavity means of a platen means, positioning a printed circuit on the substrate surface, applying uniform pressure to the printed circuit and substrate surface using another platen means having a fluid-filled bellows containing another cavity means which substantially confines a mold, which is a mirror image of the at least two-dimensional substrate surface, and laminating the printed circuit to the substrate surface.

This invention further relates to a uniform pressure transmitting apparatus for uniformly laminating a conductor to an at least two-dimensional substrate surface, comprising, (a) a first platen means having a cylinder having a plurality of diaphragms, one diaphragm separates the internal volume of the cylinder and another diaphragm, in the shape of a mold, is located at the distal end of the cylinder adjacent another platen means, the mold is the mirror image of the at least two-dimensional substrate surface and is substantially confined in a cavity means at the distal end of the cylinder, the cylinder volume located adjacent the one platen means is constructed and arranged to heat and pressurize a fluid medium occupying this volume and transfer the heat and pressure to the other volume adjacent the distal end of the cylinder, the other platen means includes another cavity means dimensioned to project a portion of the thickness of the substrate, and laminating means to bond th conductor to the substrate.

This invention also relates to a uniform pressure transmitting apparatus for uniformly laminating a printed circuit to an at least two-dimensional substrate surface, comprising, a first platen means having a cylinder having a plurality of diaphragms, one diaphragm separates the internal volume of the cylinder and another diaphragm, in the shape of a mold, is located at the distal end of the cylinder adjacent another platen means, the mold is the mirror image of the at least two-dimensional substrate surface, and is substantially confined in a cavity means at the distal end of the cylinder, the cylinder volume located adjacent the one platen means is constructed and arranged to heat and pressurize a fluid medium occupying this volume and transfer the heat and pressure to the other volume adjacent the distal end of the cylinder, the other platen means includes another cavity means dimensioned to project a portion of the thickness of the substrate, and laminating means to bond the printed circuit to the substrate.

This invention also relates to a method for uniformly laminating a conductor to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of an at least two-dimensional substrate in a cavity means of a platen means, positioning a conductor over the substrate surface, applying uniform pressure to the conductor and substrate surface using another platen means having a cylinder attached to it, which cylinder contains a plurality of diaphragms with one of the diaphragms being a mold, which is the mirror image of the substrate surface, heating and pressurizing a fluid in the cylinder volume bordered by it, the other platen means and the other diaphragm, transmitting the heat and pressure to

the cylinder volume bounded by it and the diaphragms and laminating the conductor to the substrate surface.

This invention also relates to a method for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of an at least two-dimensional substrate in a cavity means of a platen means, positioning a printed circuit over the substrate surface, applying uniform pressure to the printed circuit and substrate surface using another platen means having a cylinder attached to it, which cylinder contains a plurality of diaphragms with one of the diaphragms being a mold, which is the mirror image of the substrate surface, heating and pressurizing a fluid in the cylinder volume bordered by it, the other platen and the other diaphragm, transmitting the heat and pressure to the cylinder volume bounded by it and the diaphragms and laminating the printed circuit to the substrate surface.

Brief Description of the Drawing

This invention will now be described using the drawings which depict schematic representations and test results of the apparatus and process of the present invention. These drawings are exemplary only. They are not considered to limit the invention:

Fig. 1 shows a bellows and diaphragm used to transmit pressure;

Fig. 2 shows a combination of a cylinder and diaphragms used to transmit pressure;

Fig. 3 shows a printed circuit on a substrate;

Fig. 4A and 4B show applicants' earlier press and transfer method with Fig. 4B further showing use of pins to obtain registration of conductor on the substrate;

Fig. 5 shows results of adhesion tests performed on a conductive surface adhered to a substrate prepared using the press and method in Fig. 4A and 4B;

Fig. 6 shows the press and transfer method of this invention; and

Fig. 7 shows results of adhesion tests performed on a composite prepared according to the press and method of Fig. 6.

Detailed Description of the Invention

The present invention relates to uniform pressure transfer apparatus and a process for transferring a conductor or printed circuit carried by a release medium to a substrate to obtain uniform solder bond strength. The difficulty in obtaining uniform transfer pressure is compounded where the substrate is three-dimensional rather than two-dimensional.

Applicants' invention is directed to a silicone or other elastomeric diaphragm which has the same contour as the two or three-dimensional substrate. This diaphragm is placed at the bottom of a bellows, preferably a metallic bellows, which would contain a fluid, flowable powder, gel or deformable elastomeric powder. The contents of the bellows would be pressurized to force the diaphragm evenly against even vertical or close to vertical projections on the substrate. The pressure transfer medium can be heated with rod heaters or by heat transfer between platens. The technique eliminates the hazard of using a bladder with hot pressurized fluid which can burst or jet fluid at personnel.

An alternative embodiment is directed to using a cylinder with the lower diaphragm. The lower part of the cylinder would contain the fluid mentioned above.

The upper portion of the cylinder would contain pumped pressurized fluid and would be separated from the lower portion or section by means of a diaphragm or bellow-like diaphragm. The invention includes forming the silicone mold at the distal end of the cylinder. The invention also includes placing a substantial portion of the thickness of the substrate in a cavity of a platen.

The conductor can include a circuit alone or combined with other components. For example, adhesive, solder mask, graphics and/or transfer media.

Laminating Conductor To Substrate

A release surface carrying at least a circuit covered by adhesive is contacted with a substrate such that the circuit is adjacent the substrate surface separated therefrom by adhesive. Sufficient heat and pressure are applied to form a composite structure, using the apparatus in Fig. 3 or Fig. 5, whereby the adhesive is reacted. Thus, the circuit is transferred from the release surface and bonded to the substrate surface. In some cases, only partial curing and/or reaction need be obtained. The release surface is then separated from the composite structure.

The release surface and the substrate surface are contacted at a temperature of from about 100°C to about 230°C and preferably 140°C to 190°C. The surfaces are contacted at a pressure of from about 200 psi to about 1,200 psi and preferably 500 psi to 700 psi but not so great as to cause distortion of components. A pressure of 600 psi is preferred. Optionally, the substrate may be preheated to avoid distortion. Pressure can be applied for about 0.25 to 5 minutes, preferably 3 minutes.

In another embodiment, when the composite is formed, they are subjected to sufficient pressure during lamination to cause some compaction of the printed circuit. This causes further densification of the printed circuit, improving its conductive qualities. It has been noted that such compaction does not result in smearing of the electric circuit. Thus, the fine edges achieved in printing the electric circuit are maintained. Preferably, compaction of 25 to 40% of original printed electric pathway thickness is obtained.

This invention overcomes many deficiencies in printed circuitry fabrication in terms of simplicity, ease of operation, functional utilization and performance.

Substrate Surface

The substrate may be any known dielectric, that is, insulating or non-conducting substrate. The related application referred to above provides a detailed list of suitable substrates which can be used in this invention. Suitable substrates include those fabricated from thermoset and thermoplastic materials and their mixtures. Preferred substrates will be taught below. They can have two or three dimensional surfaces.

Thermoplastics, in general, exhibit a more complex range of chemical, thermal, and mechanical behavior than traditional thermoset printed circuit board laminates. This makes material selection for printed circuit uses even more critical. Current resin systems typically exhibit one or two desired characteristics but in general lack overall property balance to make them good printed circuit support candidates. Resin deficiencies become readily apparent during assembly operations where substrate warpage, bubbling, dimensional

instability and printed circuit delamination are common occurrences.

To address this need, applicants use engineering resins called polyarylsulfone resins. These resins offer a highly desirable property balance for circuit board uses where excellent dimensional stability, warp resistance and bonding of circuit and substrate are requirements.

Polyarylsulfone resins are characterized by inherently high heat distortion temperatures, excellent dimensional stability, creep resistance, low loss AC dielectric properties, and high mechanical strength.

Typical Properties of Polyarylsulfone Resins

Property	Units	Typical Property
Tensile Strength	psi	13,400
Elongation to Break	%	2.2
Tensile Modulus	psi	892,000
Flexural Strength	psi	19,300
Heat Deflection Temperature	°C	215
Density	gm/cc	1.55
AC Dielectrics		
Dielectric Constant		
60 Hz	--	3.86
1 KHZ	--	3.85
Dissipation Factor		
60 Hz	--	0.0042
1 KHZ	--	0.0035
Dielectric Strength		
1/8" specimen	Volts/mil	398-550
Volume resistivity at 50°C	meg ohm-cm	0.41×10^{11}

Injection Molding

Polyarylsulfone resins are easily processed utilizing standard injection molding machinery and practice. Prior to molding, resins should be dried to obtain optimum performance in a dehumidified hopper drier or circulating air oven. Utilization of a hopper drier is preferred with an inlet air temperature in the 149-163°C range and an outlet temperature not less than 135°C. When tray drying is utilized, pellets should be spread into a layer 1-2" in depth. It is important in all cases that the pellets reach and maintain a minimum temperature of 135°C for 3-4 hours. Dried resin should be molded promptly and handled carefully to preclude moisture reabsorption.

The rheological characteristics of polyarylsulfone resins provide excellent flow for filling thin and intricate wall sections typically encountered in printed wiring boards, chip carriers, and related devices. The resins process readily at stock temperatures in the 360-382°C ranges (wave soldering grade). Mold temperatures of 110-157°C are used typically with the resin for wave solderable moldings. Clean polyarylsulfone resin scrap may be reground and utilized in fabrication, provided it is properly dried and kept free of contamination.

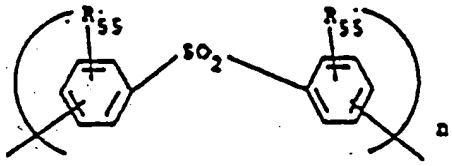
Polyarylsulfone produces warp-free moldings that are dimensionally stable both prior to and following the transfer process. Transferred circuitry exhibits tenacious adhesion to the resin as transferred, and maintains its adhesion following wave soldering.

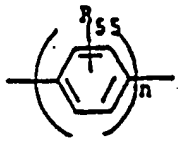
Additives which may be used with the thermoplastic and/or thermosetting resin for making the printed circuit board, include reinforcing and/or non-

reinforcing fillers such as wollastonite, asbestos, talc, alumina, clay, mica, glass beads, fumed silica, gypsum and the like; and reinforcement fibers such as aramid, boron, carbon, graphite, and glass. Glass fiber is the most widely used reinforcement in the form of chopped or milled strands, ribbon, yarn, filaments, or woven mats. Mixtures of reinforcing and non-reinforcing fillers may be used, such as a mixture of glass fibers and talc or wollastonite. These reinforcing agents are used in amounts of from about 10 to about 80 weight percent, whereas the non-reinforcing fillers are used in amounts of up to 50 weight percent. Other additives include stabilizers, pigments, flame retardants, plasticizers, processing aids, coupling agents, lubricants, mold release agents, and the like. These additives are used in amounts which achieve the desired result.

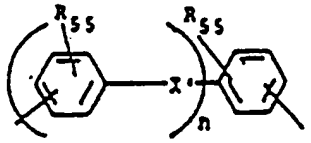
Polyarylsulfone

Polyarylsulfone is the preferred thermoplastic polymer substrate of the invention. It is an amorphous thermoplastic polymer containing units of the formula:

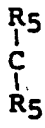
(I)  , and

(II) 

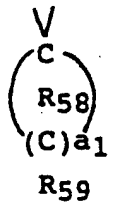
and/or

(III) 

wherein R_{55} is independently hydrog n, C_1 to C_6 alkyl to C_4 to C_8 cycloalkyl, X' is independently

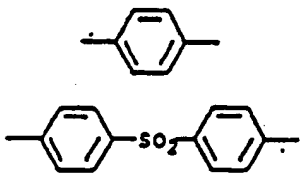


wherein R_{56} and R_{57} are independently hydrogen or C_1 to C_9 alkyl, or



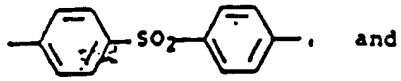
wherein R_{58} and R_{59} are independently hydrogen or C_1 to C_8 alkyl, and a_1 is an integer of 3 to 8; -S-, -O-, or  , a is an integer of 0 to 4 and n is independently an integer of 1 to 3 and wherein the ratio of unit (I) to the sum of units (II) and/or (III) is greater than 1. The units are attached to each other by an -O- bond.

A preferred polymer of this invention contains units of the formula:

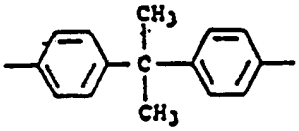


and

Another preferred polyarylsulfone of this invention contains units of the formula:



and



These units are attached to each other by an -O- bond.

The polyarylsulfone may be random or may have an ordered structure. The polyarylsulfones of this invention have a reduced viscosity of from about 0.4 to greater than 2.5, as measured in N-methylpyrolidone, or other suitable solvent, at 25°C.

Laminating Apparatus

One embodiment of this invention is directed to the use of a bellows which assists in exerting a uniform pressure across the surface of a substrate. The surface can be two-dimensional or three-dimensional. The bellows, when arranged as shown in Figure 1, assists in obtaining a uniform transfer pressure of conductor or printed circuit on a release medium to a substrate. Obtaining such a uniform transfer pressure is particularly difficult where the substrate for the circuit is three-dimensional. As shown in the schematic representation in Figure 1, heated platen 10 has a bellows 11 attached to it. The bellows can be made of metal filled with a conventional fluid. Of course, the bellows can contain the mentioned fluid but also may contain a flowable powder, gel or deformable elastomeric powder. A diaphragm 12 is attached to the bellows. The diaphragm is constrained in a cavity and is composed of a

silicone elastomer mold which is the mirror image of the surface of the substrate to which the electric circuitry is to be bonded. Preferably, the mold is silicone or can be another elastomeric diaphragm which has the same contour as the two or three-dimensional substrate. The mold is located so that during compression movement lateral to the direction of compression is avoided to the extent that uniform pressure is applied across the surface of the substrate, that is, the mold is substantially confined.

Also shown in Figure 1 is a heated platen 13 which has a cavity 14. The cavity permits insertion of a substantial portion of the substrate 15. Only as much of substrate as necessary need project so that the substrate cannot distort or move laterally during compression. Thus, the cavity substantially confines the substrate. Figure 1 also shows release medium 16 situated between diaphragm 12 and substrate 15.

In operation, substrate 15 is inserted in cavity 14. Preferably, heated platen 10 functions so that bellows 11 closes toward heated platen 13 after the release medium 16 is interposed between diaphragm or mold 12 and substrate 15. The bellows exerts a uniform pressure on diaphragm or mold 12 which in turn exerts a uniform pressure on the surface of substrate 15. The heat, which can be supplied by any conventional means, effects a uniform bonding across the surface of the substrate. Also, the pressure transfer medium can be heated with rod heaters or by heat transfer between the platens, in particular about the periphery of the surface of the substrate.

The basic components carried by the release or transfer mediums or paper are the conductor and adhesive. There are preferably more components. They include in

the order applied to the release paper before transfer: graphics or legends, solder mask, printed circuit and adhesive. The first-mentioned component is informational or educational legends to be applied to the substrate. This transfer medium facilitates manufacture of the circuit board in an expeditious manner. However, one or more components can be applied to the substrate separately. For example, the legends can be applied directly to the circuit board or multiple transfer of circuits can be done to the same substrate.

In another embodiment of the invention, a combination of cylinder and diaphragms are used to provide a uniform pressure across the surface of the substrate. This is shown in Figure 2. As shown in that Figure, heated platen 17 has a cylinder 18 fixed to it. The cylinder contains two diaphragms. One diaphragm is an isolation diaphragm or bellows-like diaphragm 19 which separates a pressurized fluid contained in one part 20 of the cylinder 18. The pressurized fluid can be polyglycol. The fluid can enter at 21, exit at 22 and be recycled. Of course, this fluid can be heated using conventional means not shown. Diaphragm 23 is located at the distal end of the cylinder providing a second portion 24 of the cylinder 18. The second portion contains a flowable powder or gelled fluid or silica gel or deformable elastomeric powder. This latter medium transfers pressure exerted from the upper part of the cylinder via diaphragm 19. Diaphragm 23 is positioned at the distal end of cylinder 18. The diaphragm is preferably composed of a silicone elastomer as in the previous embodiment and takes the same contour as the surface of the substrate 15. Release medium 16 overlays the substrat 15 prior to bonding. Of c urse, the

releasable medium or paper, as in the previous embodiment, is removed after laminating the printed circuit on the substrate. As in the previous embodiment, the substrate 15 is inserted into a cavity 25 located in heated platen 26.

In operation, substrate 15 is inserted in heated platen 26. A release paper is placed in registration on the surface of the substrate 15. Cylinder 18 closes toward the substrate. When the diaphragm meets the substrate 15, pressure and heat are exerted by the pressurized fluid in portion 20 of the cylinder 18. That heat and pressure are transferred via isolation diaphragm 19 to the medium in portion 24 of cylinder 18. This in turn provides a uniform pressure over the surface of the substrate 15 and assists in laminating the printed circuit to the substrate uniformly across the surface of the substrate, in particular, about the perimeter of the substrate 15.

Overall, the embodiments of this invention provide a technique which eliminates the hazard of using a bladder with hot pressurized fluid which can burst or jet fluid at personnel.

Intended Use

The transfer of circuitry can be made to take place over planar or a three-dimensional substrates to the extent the surface is "developable". For example, a three-dimensional circuit can be transferred to an injection molded substrate.

Uses for the process are aimed at such three-dimensional type devices in high volume where the speed of the printing process for the circuit and the efficiency of the use of injection molded substrate can be utilized cost-effectively.

Specifically, planar or shallow three-dimensional circuit boards can be efficiently produced using the process. Also, with some process modification, a series of molded plastic chip carriers can be tooled and produced. These plastic chip carriers utilize a pre-molded thermoplastic substrate and a transfer process to apply the conductors, which are subsequently plated to accommodate wire bonding and soldering operations.

These chip carriers are manufactured from the same resin system that is used in the circuit boards; and when they are used together, there is no thermal mismatch between the chip carrier and the circuit board.

An automotive use includes molding a circuitry to the inside roof portion of an automobile having dome light circuitry.

Example

The invention will now be described with examples of the teachings set forth above. These examples are exemplary and not exclusive. They are not considered limiting. Concentrations are percent by weight unless otherwise indicated.

Example 1

The following ingredients in percent by weight are blended together at room temperature:

(I) 1.81 percent polyhydroxyether known as Phenoxy PKFE,

(II) 2.75 percent 3,4 epoxy cyclohexyl methyl 3,4 epoxy cyclohexyl carboxylate known as epoxy ERL-4221, and

(III) 8.47 percent diethylene glycol monobutyl ether acetate known as butyl Carbitol acetate.

To this mixture is added the following ingredients:

(IV) 82.62 percent of silver powder from Metz Metallurgical Co. known as METZ EG200ED; and

(V) 4.35 percent of silver flake also from Metz Metallurgical Co. known as METZ 50S.

More particularly, the phenoxy resin is dissolved in diethylene glycol monobutyl ether acetate with agitation. The epoxy resin is added to this mixture while agitation is continued. Then, silver powder is added to the mixture under continued agitation until it is dispersed to a Hegman grind of six. Then, the silver flake is added until it is also dispersed to a grind of six or better. The viscosity of the mixture is 35,000 cps as determined with a Brooksfield RVT Viscometer at 24°C using a number six spindle at 20 rpm. The 2.5/20 rpm viscosity ratio is 4. The conductive metal and binder are mixed together until completely homogenized to form an ink.

This conductive ink is screen printed (U.S. Sieve size 230), using conventional techniques, onto VNS Supermat release paper (obtained from S.D. Warren Co., Westbrook, Maine) to a thickness of approximately 1 mil after drying.

The printed paper is dried in a forced convection oven at 96°C for ten minutes.

Separately, an adhesive containing the following ingredients is prepared:

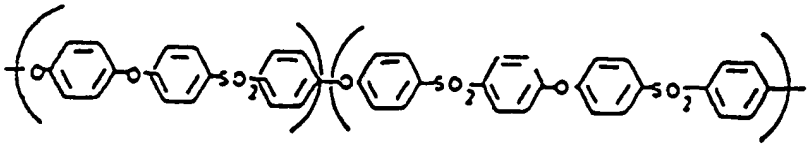
TRADE NAME	CHEMICAL NAME	NEW (WT.%)
PHENOXY PKFE	POLYHYDROXY ETHER	18.99
RESIMENE 2040	MELAMINE FORMALDEHYDE	0.95
BUTYL CARBITOL ACETATE	DIETHYLENE GLYCOL MONO BUTYL ETHER ACETATE	75.96
BLACK SAPL	NIGROSINE BLACK	0.19
BENZOIC ACID	BENZOIC ACID	0.05
CABOSIL	SILICA	3.86

Making The Adhesive

The polyhydroxyether or phenoxy resin is dissolved in the diethylene glycol monobutyl ether acetate using high speed mixing until all the resin particles are dissolved. The melamine formaldehyde resin is then added. The nigrosine black and benzoic acid are mixed together and then added with high shear agitation. The high surface area silica is then added with high shear mixing. The entrained air is removed with vacuum. The viscosity of the adhesive composition measured with an RVT Viscometer at 24°C using a number six spindle at 20 rpm is 35,000 cps with a 2.5/20rpm viscosity ratio of 4.

The prepared adhesive is screen printed in registration on top of the conductor surface of the printed circuit which is already dried. Then, the adhesive coated circuit is placed in a forced convection oven at 96°C for 10 minutes until the adhesive coat is dry but not fully cured.

A substrate is molded from a composition containing 78 weight percent of a polymer containing the following unit:



having a reduced viscosity of 0.61 dl/g as measured in N-methyl-pyrrolidinone (0.2 g/100 ml) at 25°C. The composition also contains 10 weight percent mica and 10 weight percent of chopped glass fibers obtained from Owens Corning.

The substrate composition is injection molded using conventional conditions. A 6x6 plaque which is 0.06" thick is molded. The melt temperature is 377°C, and the mold temperature is 305°F. The injection speed is 35mm/sec, and the injection molding pressure is 100 bars for 7 sec.

The substrate sheet is vapor polished with methylene chloride for about one second.

The substrate is placed in a compression platen press as shown in Figures 4 and 6 with the release paper containing the conductor (1.0-1.2 mils dry film thickness) and the adhesive printed in the registration (0.6-0.8 mils dry film thickness). One of the platens is fitted with a diaphragm or bellows as shown in each of the Figures. Then it is molded at 600 psi for 3 minutes at 177°C after the release paper is stripped away.

The circuit board is then cured in an oven at 150°C for 30 minutes. After cure, the board can be soldered with a hand soldering iron or in a wave solder machine set at 246°C with a carrier speed of 6 ft/min. The electrical resistance of a square serpentine pattern was measured with a milliohm meter. Consistent values in the range of 5-10 milliohms/1 mil square are obtained.

Comparative tests are conducted using an earlier press shown in Figures 4A and 4B and a press according to the teachings of this invention shown in Figure 6. In each test, a substrate having a two-dimensional surface is placed on or in a platen. The thickness which protrudes is 20 mils. The release or transfer paper with printed circuit and adhesive components is placed on it. The board and transfer medium are compressed by closing the platens. Lamination is achieved using a pressure of 600 psi, a temperature of 177°C and a time of three minutes. Then the release paper is removed, and the circuitized substrate is cured at 150°C for thirty minutes. After cure, the board can be soldered with a hand soldering iron or in a wave solder machine set at 246°C with a carrier speed of 6 ft/mm.

For bond strength determination, copper wires (.05/inch diameter) are soldered onto 1/4 inch diameter pads of the circuit board. After cooling, the wires are pulled from the boards clamped onto the base of a Chatillon tensile tester Model UTSM. The wires are hooked onto the end of a AMETEK ACCU Force Gage II. The circuit board is then lowered at the #1 setting of the Chatillon tester, and the maximum force is measured to break the bond between the wire and the 1/4 inch pad on a 1/16 inch substrate board. The sample obtained using the prior art press showed the non uniform test results of Figure 5. Those obtained using the process of this invention showed the uniform results of Figure 7.

Figure 5 shows an average tensile strength of 25.06 lbs or in other words 510.5 psi with 13% of the failures in the substrate. However, Figure 7 shows an

average tensile strength 48.1 lbs or 980.6 psi with 91% of failures in the substrate.

While these results are very impressive, each figure shows the test results at different locations on a circuit board like that of Figure 3. Each of the sixteen circuits were tested. The tensile strength measurement for the adhesion bond of each circuit is shown with the bond strength determination for the soldered wire shown in the upper right hand corner. Failures are designated "P" or "S" to indicate plug (plastic board) or snap (circuit interface) failures, respectively. In Figure 5, the prior art technique shows the least bond strength about the perimeter of the circuit board. However, Figure 6 according to this invention shows superior, uniform bond strength all over the circuit board compared to the results of Figure 5 tests.

Example 2

Example 1 is repeated except that both sides of the circuit board are laminated with a printed circuit.

Example 3

Example 1 is repeated except that the surface of the circuit board upon which circuitry is applied is three-dimensional.

Although the invention has been described in conjunction with specific embodiments, it is evident that many alternatives and variations will be apparent to those skilled in the art in light of the foregoing description. This may include optionally plating the printed circuit even though the circuit is solderable without this treatment. This may also include reversing the platen arrangement so that the substrate is above the platen housing the mold. Also, both sides of the substrate may be processed. Accordingly, the

invention is intended to embrace all of the alternatives and variations that fall within the spirit and scope of the appended claims.

CLAIMS

1. A uniform pressure transmitting apparatus for uniformly laminating a conductor to an at least two-dimensional substrate surface comprising, (a) a first platen means having a fluid filled bellows with a first cavity means substantially confining a mold which is a mirror image of the at least two-dimensional substrate surface, (b) a second platen means containing a second cavity means dimensioned to protrude a portion of the thickness of the substrate, (c) pressurization means for compressing a conductor overlaid on the substrate surface, and (d) laminating means to bond the conductor to the substrate surface.

2. The transmitting apparatus according to claim 1, wherein the surface of the substrate is three-dimensional.

3. The transmitting apparatus according to claim 1, wherein the mold is composed of silicone rubber.

4. The transmitting apparatus according to claim 1, wherein the substrate is plastic.

5. The transmitting apparatus according to claim 4, wherein the substrate is thermoplastic.

6. The transmitting apparatus according to claim 4, wherein the plastic is polyarylsulfone.

7. The transmitting apparatus according to claim 1, wherein the bellows is made of metal.

8. The apparatus according to claim 1, wherein the fluid contained in the bellows is a liquid flowable powder, gel or deformable elastomer powder.

9. The apparatus according to claim 1, wherein the conductor is a printed circuit.

10. A uniform pressure transmitting apparatus for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, (a) a first platen means having a fluid filled bellows with a first cavity means substantially confining a mold which is a mirror image of the at least two-dimensional substrate surface, (b) a second platen means containing a second cavity means dimensioned to protrude a portion of the thickness of the substrate, (c) pressurization means for compressing a printed circuit positioned on the substrate surface, and (d) laminating means to bond the printed circuit to the substrate surface.

11. A method for uniformly laminating a conductor to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of the substrate in a cavity means of a platen means, positioning a conductor onthe substrate surface, applying a uniform pressure to the conductor and substrate surface using another platen means having a fluid-filled bellows containing another cavity means which substantially confines a mold, which is a mirror image of the at least two-dimensional substrate surface, and laminating the conductor to the substrate surface.

12. The method according to claim 11, wherein the substrate surface is three-dimensional.

13. The method according to claim 11, wherein the lamination is effected with heat.

14. The method according to claim 11, wherein the mold is made of silicone rubber.

15. The method according to claim 11, wherein the substrate is made of plastic.

16. The method according to claim 15, wherein the substrat is made of thermoplastic.

17. The method according to claim 15, wherein the plastic is polyarylsulfone.

18. The method according to claim 11, wherein the bellows is a metal bellows.

19. The method according to claim 11, wherein the fluid is a liquid flowable powder, gel or deformable elastomer powder.

20. The method according to claim 11, wherein the conductor is a printed circuit.

21. A method for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, inserting a substantial portion of the thickness of the substrate in a cavity means of a platen means, positioning a printed circuit on the substrate surface, applying uniform pressure to the printed circuit and substrate surface using another platen means having a fluid-filled bellows containing another cavity means which substantially confines a mold, which is a mirror image of the at least two-dimensional substrate surface, and laminating the printed circuit to the substrate surface.

22. A uniform pressure transmitting apparatus for uniformly laminating a conductor to an at least two-dimensional substrate surface, comprising, (a) a first platen means having a cylinder having a plurality of diaphragms, one diaphragm separates the internal volume of the cylinder and another diaphragm, in the shape of a mold, is located at the distal end of the cylinder adjacent another platen means, the mold is the mirror image of the at least two-dimensional substrate surface and is substantially confined in a cavity means at the distal end of the cylinder, the cylinder volume located adjacent the one platen means is constructed and arranged

to heat and pressurize a fluid medium occupying this volume and transfer the heat and pressure to the other volume adjacent the distal end of the cylinder, the other platen means includes another cavity means dimensioned to project a portion of the thickness of the substrate, and laminating means to bond the conductor to the substrate.

23. The apparatus according to claim 22, wherein the substrate surface is three-dimensional.

24. The apparatus according to claim 22, wherein the mold is made of silicone rubber.

25. The apparatus according to claim 22, wherein the substrate is plastic.

26. The apparatus according to claim 25, wherein the substrate is thermoplastic.

27. The apparatus according to claim 25, wherein the substrate is polyarylsulfone.

28. The apparatus according to claim 22, wherein the fluid is polyglycol.

29. The apparatus according to claim 22, wherein the fluid is recycled.

30. The apparatus according to claim 22, wherein the transfer medium is a flowable powder, gelled fluid, silicone gel, or deformable elastomer powder.

31. The apparatus according to claim 22, wherein the conductor is a printed circuit.

32. A uniform pressure transmitting apparatus for uniformly laminating a printed circuit to an at least two-dimensional substrate surface, comprising, a first platen means having a cylinder having a plurality of diaphragms, one diaphragm separates the internal volume of the cylinder and another diaphragm, in the shape of a mold, is located at the distal end of the cylinder adjacent another platen means, the mold is the mirror

image of the at least two-dimensional substrate surface, and is substantially confined in a cavity means at the distal end of the cylinder, the cylinder volume located adjacent the one platen means is constructed and arranged to heat and pressurize a fluid medium occupying this volume and transfer the heat and pressure to the other volume adjacent the distal end of the cylinder, the other platen means includes another cavity means dimensioned to project a portion of the thickness of the substrate, and laminating means to bond the printed circuit to the substrate.

33. A method for uniformly laminating a conductor to an at least two-dimensional substrate surface comprising, inserting a substantial portion of a thickness of an at least two-dimensional substrate in a cavity means of a platen means, positioning a conductor over the substrate surface, applying uniform pressure to the conductor and substrate surface using another platen means having a cylinder attached to it, which cylinder contains a plurality of diaphragms with one of the diaphragms being a mold, which is the mirror image of the substrate surface, heating and pressurizing a fluid in the cylinder volume bordered by it, the other platen means and the other diaphragm, transmitting the heat and pressure to the cylinder volume bounded by it and the diaphragms and laminating the conductor to the substrate surface.

34. The method according to claim 33, wherein the substrate surface is three-dimensional.

35. The method according to claim 33, wherein the mold is a silicone rubber mold.

36. The method according to claim 33, wherein the substrate is plastic.

37. The method according to claim 36, wherein the substrate is thermoplastic.

38. The method according to claim 36, wherein the plastic is polyarylsulfone.

39. The method according to claim 33, wherein the fluid is a polyglycol.

40. The method according to claim 33, wherein the fluid is recycled.

41. The method according to claim 33, wherein the transfer medium is a flowable powder, gelled fluid, silicone gel or deformable elastomer powder.

42. The method according to claim 33, wherein the conductor is a printed circuit.

43. A method for uniformly laminating a printed circuit to an at least two-dimensional substrate surface comprising, inserting a substantial portion of a thickness of an at least two-dimensional substrate in a cavity means of a platen means, positioning a printed circuit over the substrate surface, applying uniform pressure to the printed circuit and substrate surface using another platen means having a cylinder attached to it, which cylinder contains a plurality of diaphragms with one of the diaphragms being a mold, which is the mirror image of the substrate surface, heating and pressurizing a fluid in the cylinder volume bordered by it, the other platen and the other diaphragm, transmitting the heat and pressure to the cylinder volume bounded by it and the diaphragms and laminating the printed circuit to the substrate surface.

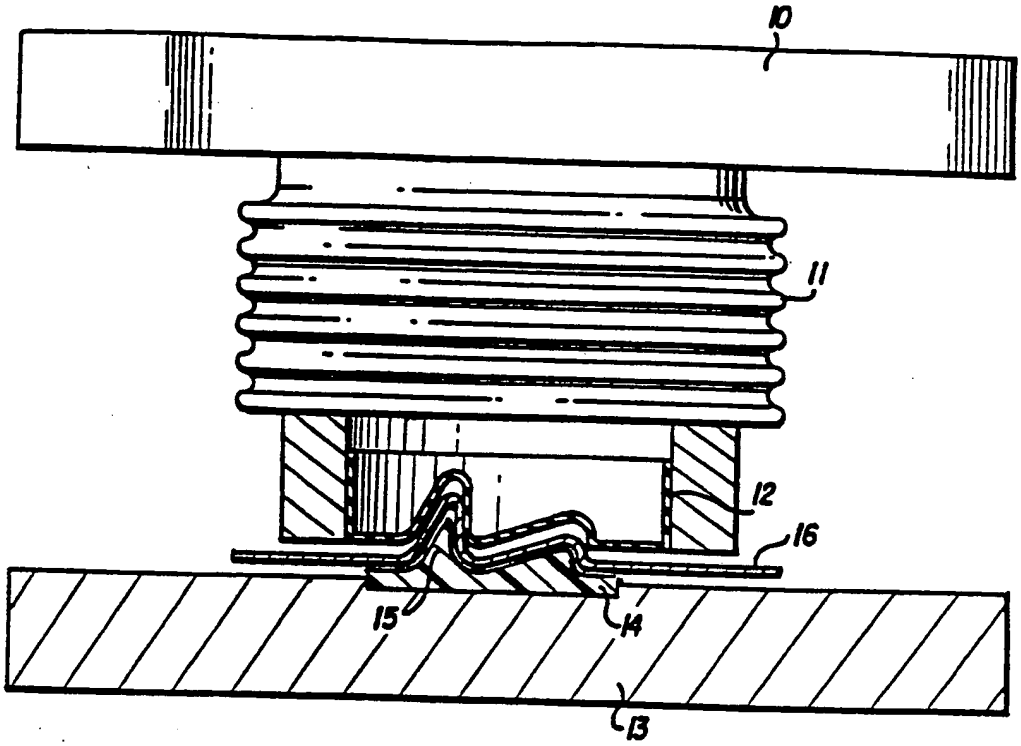

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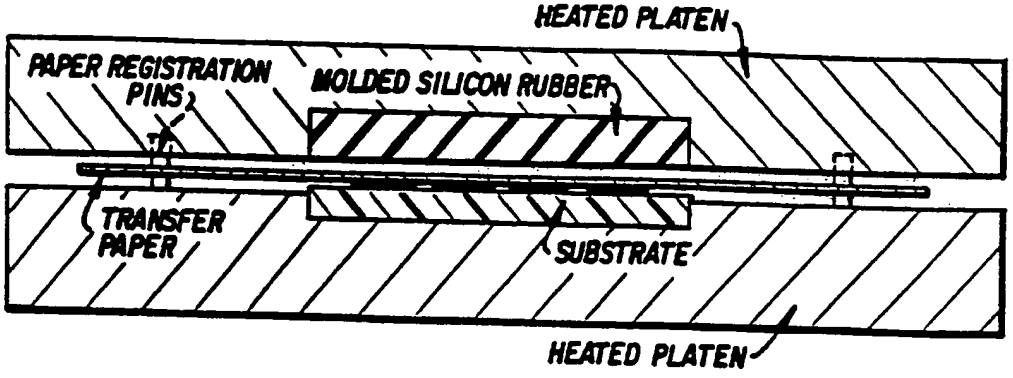
FIG. 1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MOLDED SILICON RUBBER
TRANSFER PAPER
SUBSTRATE
HEATED PLATEN

FIG. 6

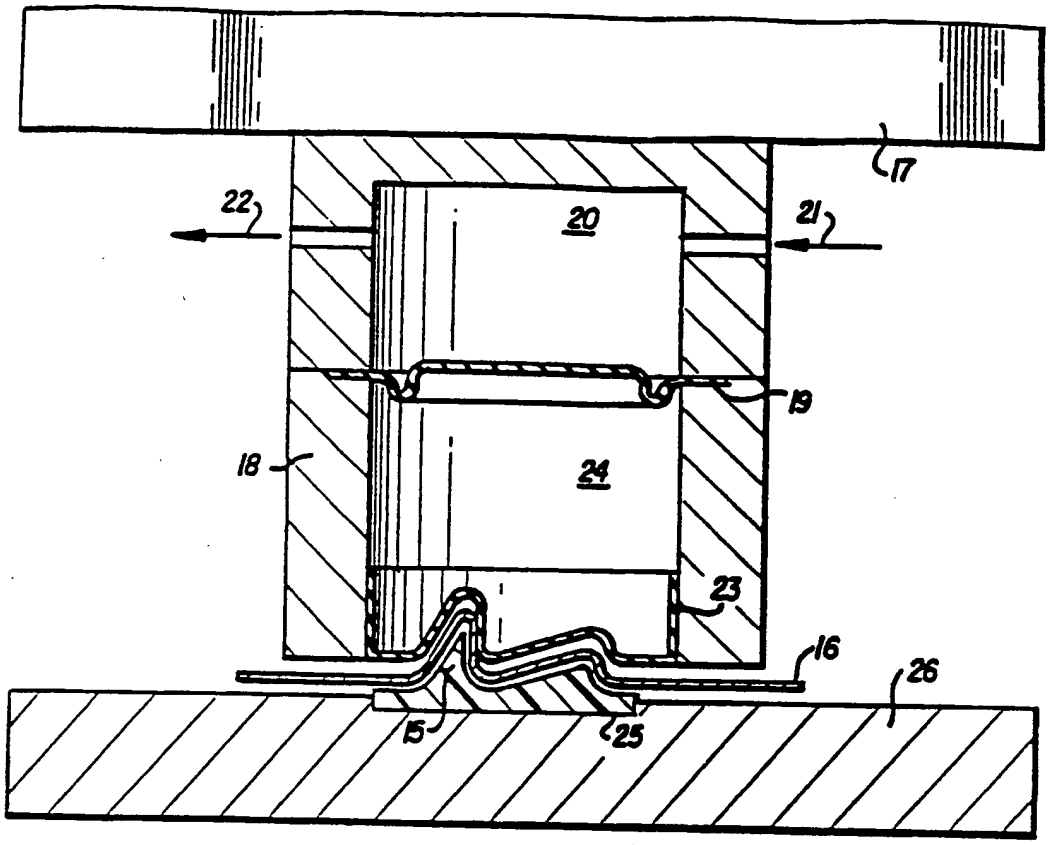


FIG. 2

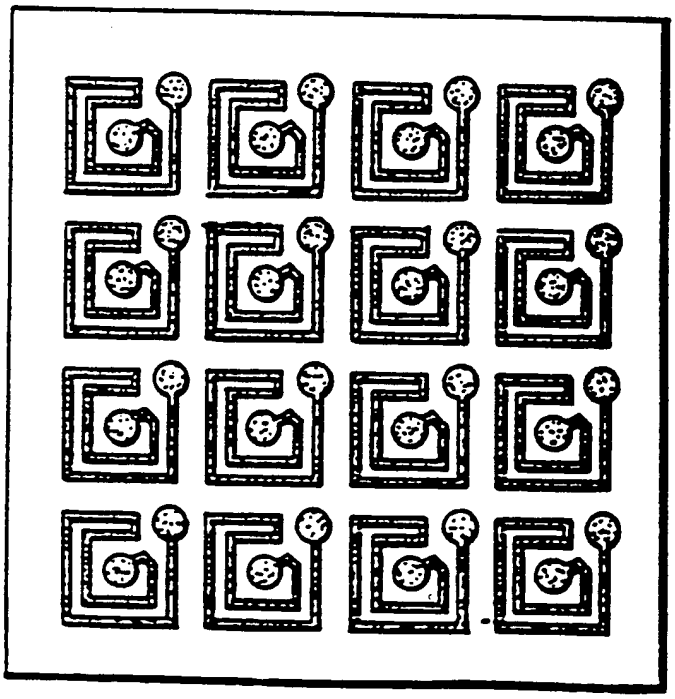
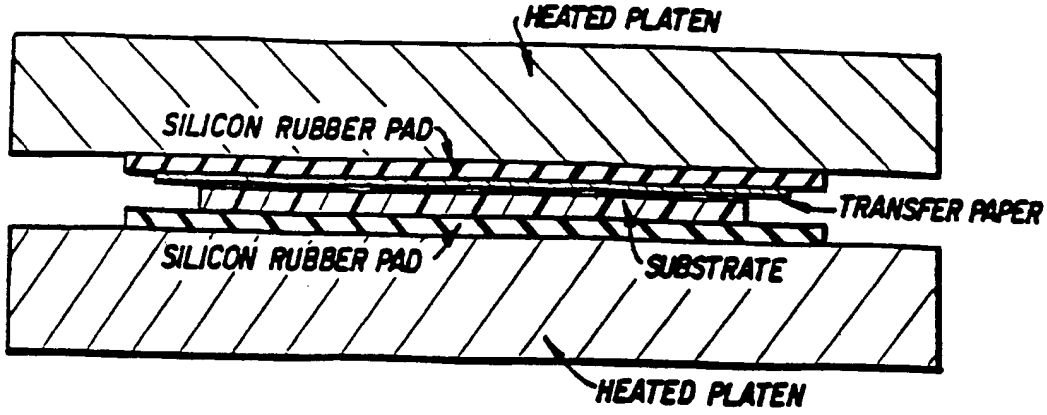


FIG. 3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SILICON RUBBER PAD
TRANSFER PAPER
SILICON RUBBER PAD
SUBSTRATE
HEATED PLATEN

FIG. 4A

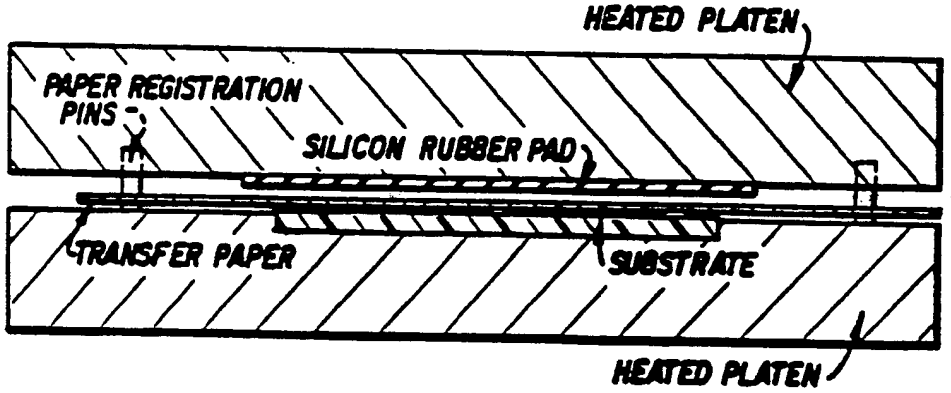
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FIG. 4B

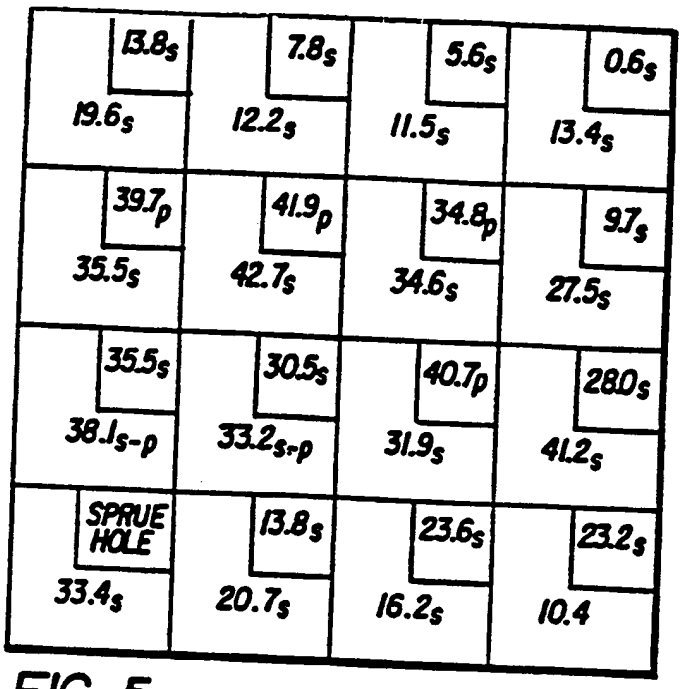
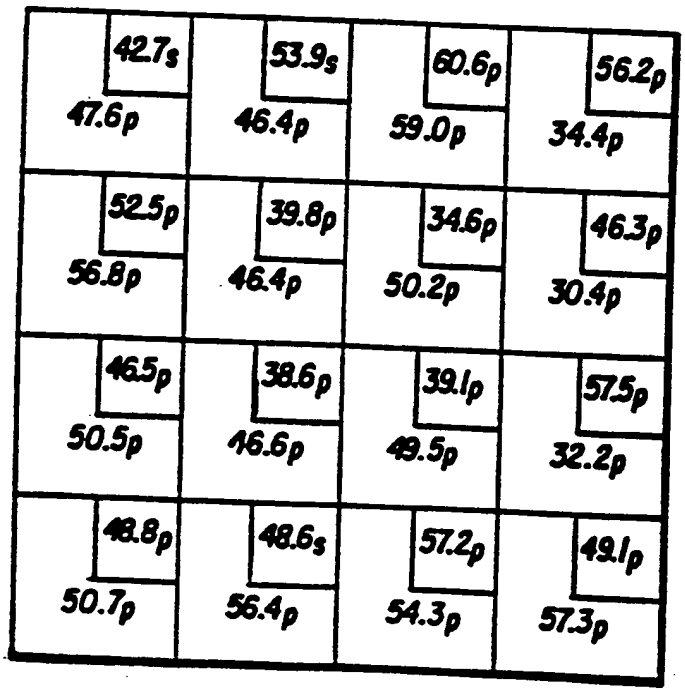


FIG. 5 PRIOR TRANSFER METHOD

FIG. 7 IMPROVED TRANSFER METHOD



INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/02138

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): B30B 5/02; B44C 1/165

U.S. CL.: 100/211; 156/213,230,240,475,583.3; 264/313

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	100/211; 156/212,213,230,240,285 475,581,583.3; 264/313

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
X	U.S. 4,806,195 (NAMYSI) 21 February 1989 See the entire document.	1,3-7,9-11,13-22, 24-33,35-43
X	U.S., 4,636,275 (NORELL) 13 January 1987 See the entire document.	1-43
X	U.S., 3,984,273 (SAID) 05 October 1976 See the entire document.	2,8,12,23,34
X	U.S., 4,700,474 (CHOINSKI) 20 October 1987 See the entire document.	1-43
X	U.S., 4,148,597 (LARSEN) 10 April 1979 See the entire document.	1,10,11,21,22,32, 33,43
X	U.S., 2,519,661 (JOHNSON) 22 August 1950 See the entire document.	1-43

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
11 JULY 1990	19 SEP 1990
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	JAMES J. ENGEL

Form PCT/ISA/210 (second sheet) (May 1986)